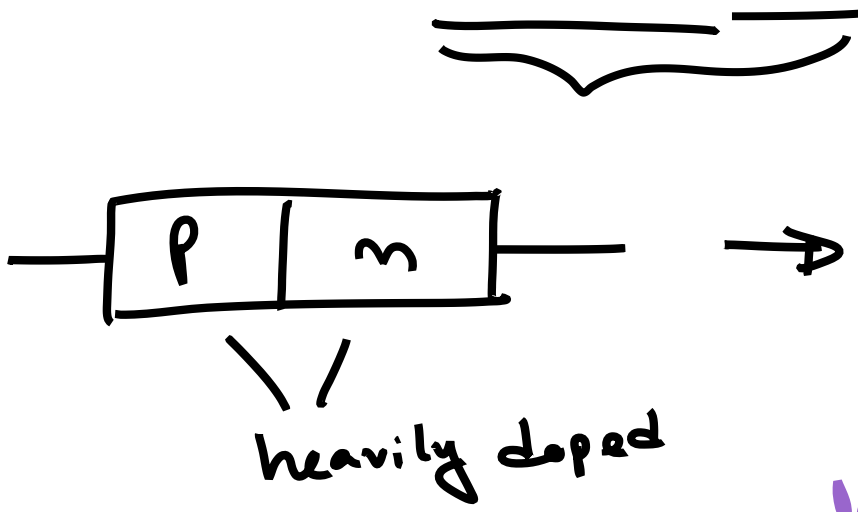
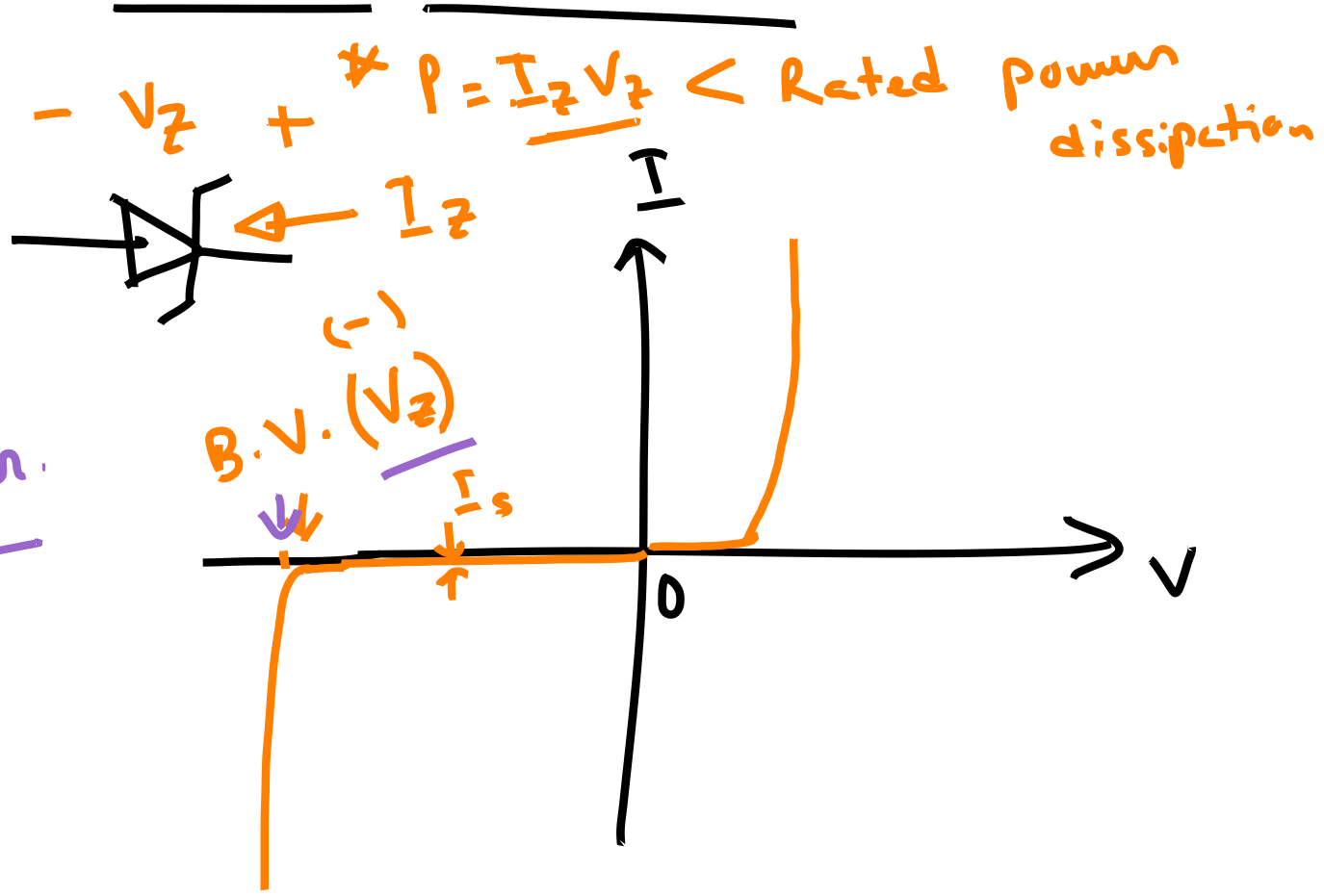
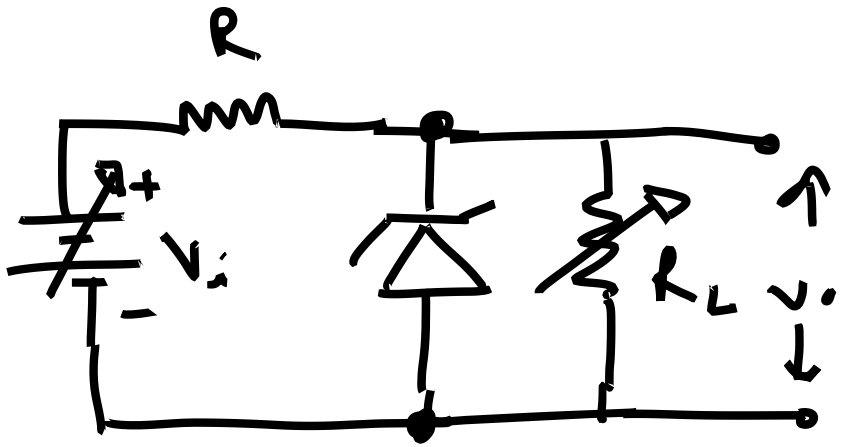
Zener diode as voltage regulator



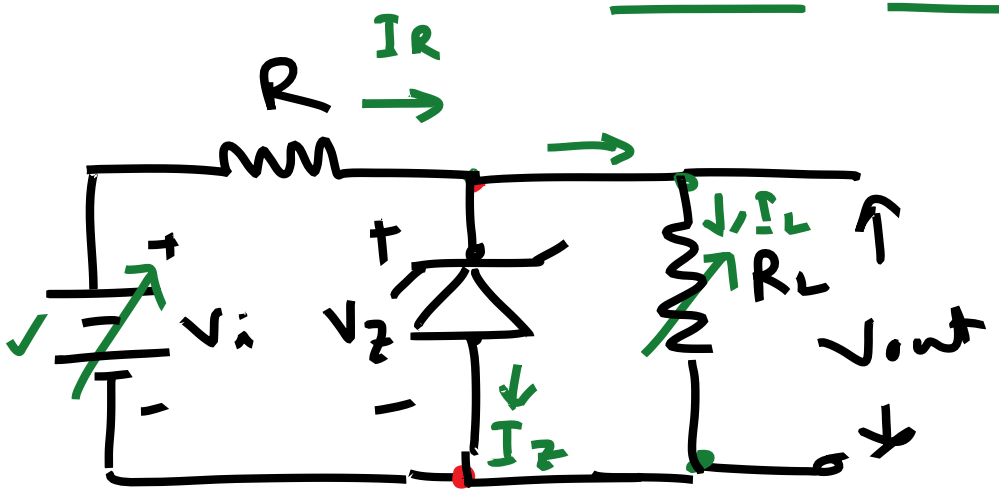
Voltage regulator

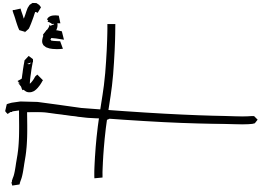




→ Zener diode → Reverse bias → Breakdown region

Zener diode as voltage regulator





$$V_{Th} = V_i \times \frac{R_L}{R + R_L} \geq V_z$$

$$I_R = I_L + I_z, \quad I_z = I_R - I_L$$

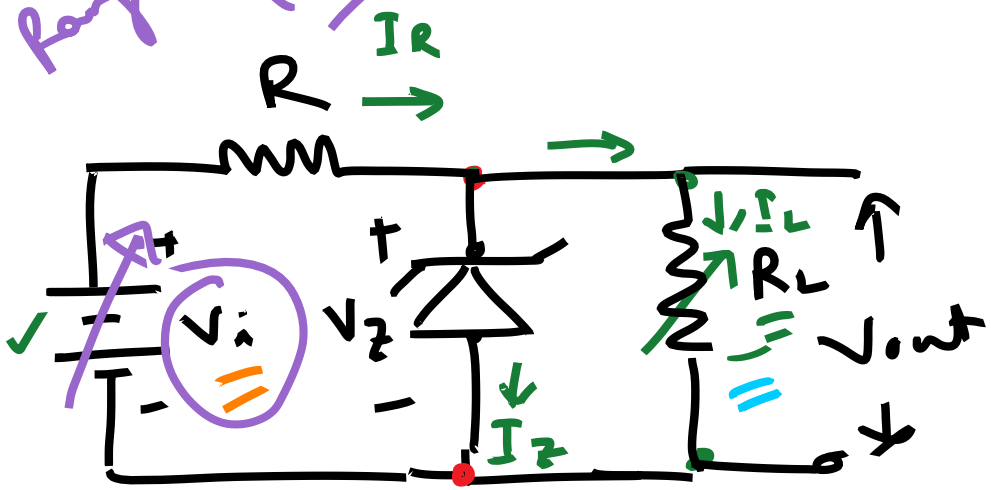
$$I_R = \frac{V_i - V_z}{R}, \quad I_L = \frac{V_z}{R_L}$$

$$I_z = \frac{V_i - V_z}{R} - \frac{V_z}{R_L}$$

Power dissipation in Zener

$$P_z = I_z V_z < \text{Rated Power}$$

Zener diode as voltage regulator



$R_{L,min}$, $R_{L,max}$

$V_L = V_i \times \frac{R_{L,min}}{R + R_{L,min}} = V_z$

$R_{L,min} = \frac{V_z R}{V_i - V_z}$

$R_{L,max} = \frac{V_z}{I_{L,min}}$

$R_{L,min}$, $I_{L,max} = \frac{V_z}{R_{L,min}}$

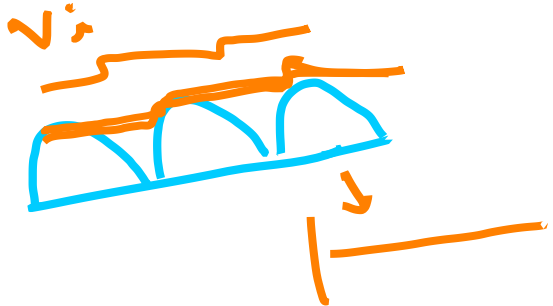
when, R_L is max., I_L is min

I_z is max.

$I_R = I_{L,max} + I_{z,min}$, $I_{z,min} = ??$

$I_{z,max} \; V_z = P_{z,max}$

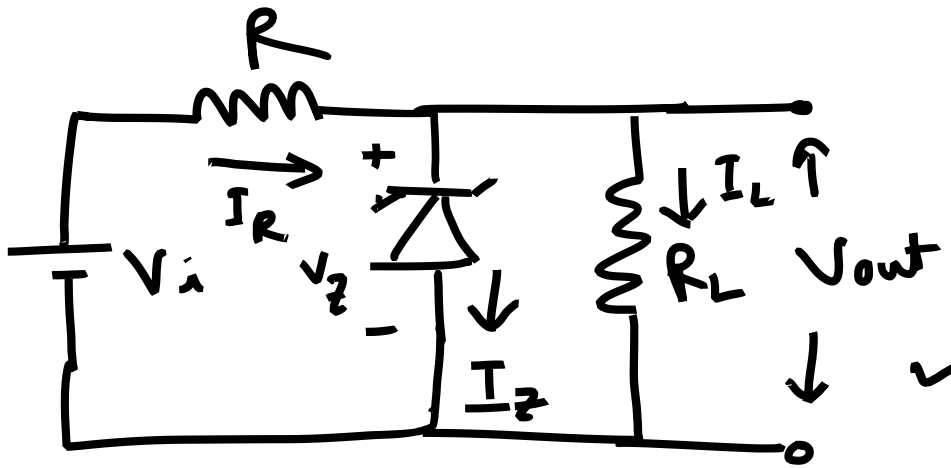
$I_{z,max} = ?? = \frac{P_{z,max}}{V_z}$



$P_{z,min} = V_z \; I_{z,min}$

$\rightarrow I_{L,min} = I_R - I_{z,max} = \frac{V_i - V_z}{R} - \frac{P_{z,max}}{V_z}$

Zener diode as voltage regulator



$$R = \frac{V_i - V_z}{I_R} = \frac{V_i - V_z}{I_z + I_L}$$

(i) I_z min, I_L is max and V_i is min

(ii) I_z max, I_L is min & V_i is max

(i) $$R = \frac{V_{i,min} - V_z}{I_{z,min} + I_{L,max}}$$

(ii) $$R = \frac{V_{i,max} - V_z}{I_{z,max} + I_{L,min}}$$

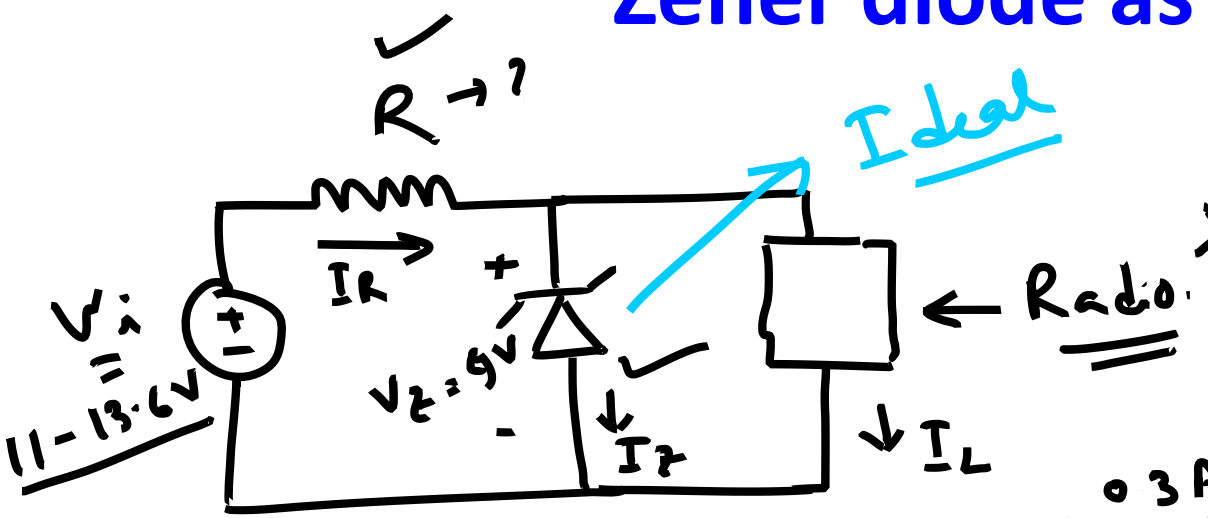
$$(V_{i,min} - V_z)(I_{z,max} + I_{L,min}) = (V_{i,max} - V_z)(I_{z,min} + I_{L,max})$$

Assumption * $I_{z,min} = 10\%$ of $I_{z,max}$

$= 0.1\, I_{z,max}$

$$I_{z,max} = \frac{I_{L,max}[V_{i,max} - V_z] - I_{L,min}[V_{i,min} - V_z]}{V_{i,min} - 0.9V_z - 0.1V_{i,max}}$$

Zener diode as voltage regulator



$I_{L,min} = 0$, $I_{L,max} = 100\,mA$

$V_Z = 9\,V$ $\quad I_{Z,max} \simeq 300\,mA \rightarrow 0.3\,A$, $P_{Z,max} = V_Z \cdot I_{Z,max}$

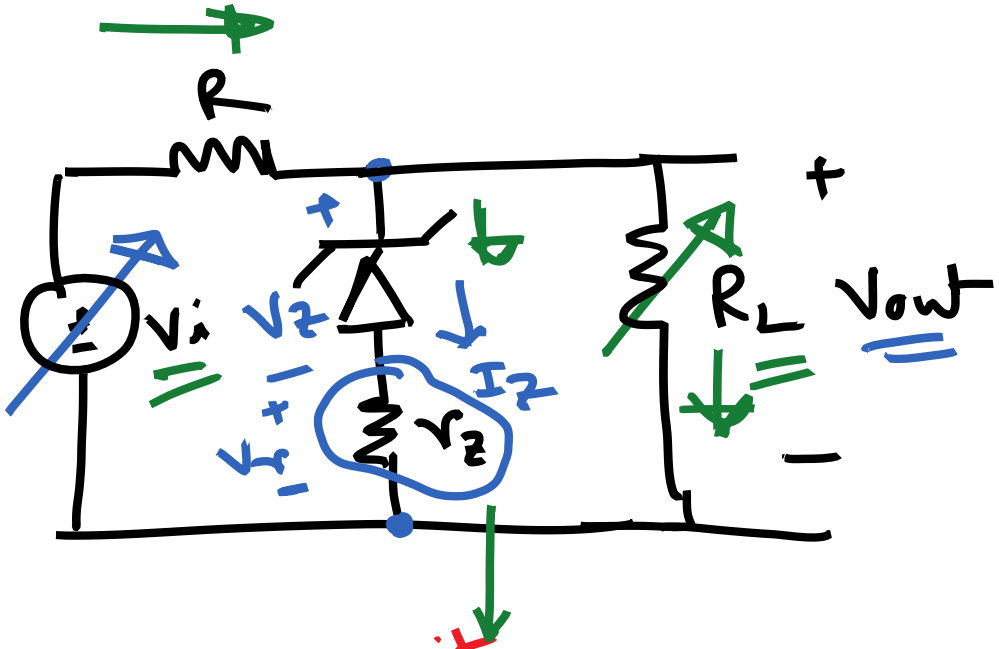
$P_{Z,max} = 2.7\,W$ ✓

$$R = \frac{V_i - V_Z}{I_L + I_Z} = \frac{13.6 - 9}{0 + 0.3} = 15.3\,\Omega$$ ✓

$$P_{R,max} = \frac{(13.6 - 9)^2}{15.3} \approx 1.4\,W$$ ✓

Effect of Zener Resistance ✓ ✓

Zener diode as voltage regulator



$$V_{out} = V_Z + V_r$$

$$V_{out} = V_Z + I_Z r_z$$

$$V_{out} = V_z + I_z r_z$$

Two figures of merit

1. Source regulation
2. Load regulation

→ example

Practical Zener diode